

# GLOBAL WARMING AND HURRICANES

William M. Gray \*  
Colorado State University, Fort Collins, Colorado

**“Global warming caused by human activity might be the greatest  
hoax ever perpetrated on the American people”**  
*Senator James Inhofe (R., Oklahoma) 2003*

## 1. INTRODUCTION

The ocean fully ventilates itself every 1-2 thousand years through a polar region (Atlantic and Antarctic) deep ocean subsidence of cold-saline water and a compensating upwelling of warmer less saline water in the tropics (Figures 1 and 2). This deep ocean circulation continuously acts to cool the ocean. Ocean bio-life depends on this deep ocean ventilation.

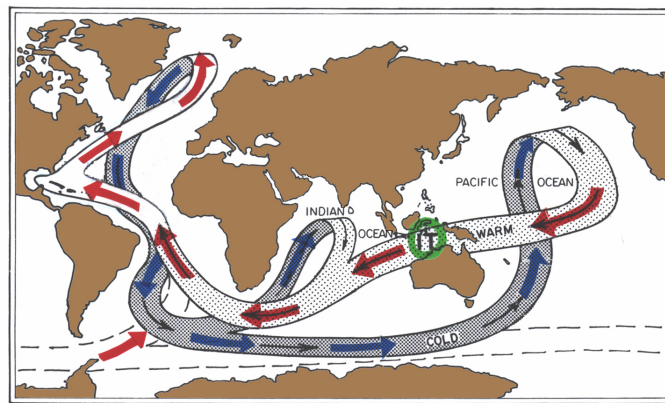


Figure 1. Idealized global ocean conveyor belt or THC.

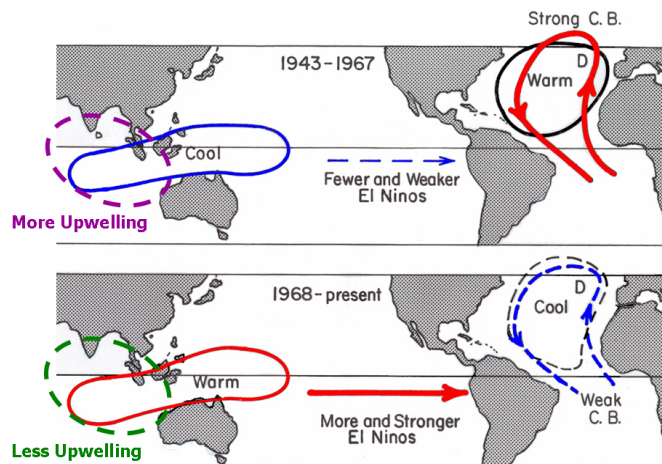


Figure 2. Differences in tropical upwelling and SST when the conveyor belt or THC is strong (top) and weak (bottom).

Paleo and meteorological observations show that there have been decadal to multi-century scale variations in the strength of this global deep water or Thermohaline Circulation (THC) over the last thousand years. When the THC circulation is stronger than average the earth-system tends to cool (with a 10-15 year lag) (Figure 3). When the THC is, by contrast, weaker than average, the earth-system, with a similar lag time, tends to warm (Figure 4). The average THC circulation cools the oceans by about  $3 \text{ w/m}^2$ . When the THC is stronger than average, this cooling is estimated to be about  $4 \text{ w/m}^2$ ; when it is weaker than average, it is estimated to be about  $2 \text{ w/m}^2$ , or approximately half as much.

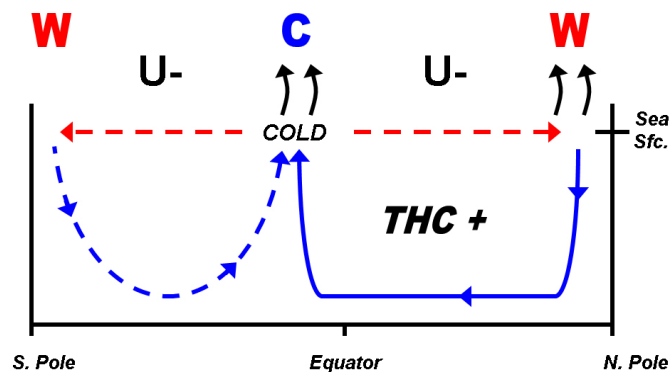


Figure 3. Idealized N-S cross-section of ocean circulation when the THC is strong (THC+). Zonal winds are weaker than average and with a lag the earth-system tends to cool.

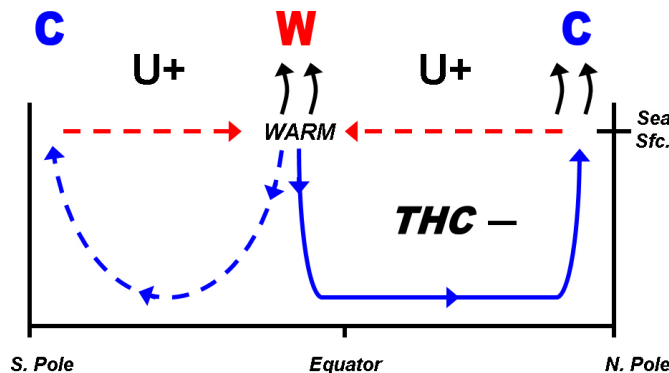


Figure 4. Same as Figure 3, but when the THC is weaker than average and zonal winds are stronger than average. The earth system tends to warm during these periods.

Besides this deep ocean global THC circulation, there are also mass compensating upper-ocean Ekman-type frictionally forced up-and-downwelling ocean areas which are a product of the ocean's horizontal surface wind configurations. These Ekman up-and-downwelling patterns can also contribute to local and global temperature change depending upon where they occur. These combined THC and Ekman ocean-induced global circulation changes have no direct association with anthropogenic

greenhouse gas increases. In the author's view, most of the last 30-year and last century-and-a-half global warming that has occurred can be attributed to these types of ocean induced circulation changes brought about by a general long-period slow-down of the global THC. Global Circulation Models (GCMs) which do not account or accurately model these global-scale ocean circulation features are quite inadequate for understanding the observed last century-and-a-half and last 30-year global temperature increases that have occurred. This is the current situation in which GCMs have grossly exaggerated the influence of anthropogenic greenhouse gas increases as the primary cause of such warming. The GCMs have not yet taken into consideration the functioning of the ocean's deep water circulation.

## **2. GLOBAL WARMING**

The global warming of the last century-and-a-half ( $\sim 0.7^{\circ}\text{C}$ ) and the last 30 years ( $\sim 0.5^{\circ}\text{C}$ ) (Figure 5) is hypothesized to be a consequence of the slowdown of the global THC circulation due to Atlantic Ocean salinity decreases and a concomitant reduction in Antarctic deep-water formation and response tropical ocean upwelling of cold water into the upper mixed layer. This THC weakening has brought about a decrease in net ocean evaporation-rainfall. It is this reduced ocean evaporation cooling that has been primarily responsible for the observed global warming that has occurred. The THC slowdown has led to a direct warming of the tropical oceans through decreased upwelling of cold water. This tropical warming has led to an increase in the tropical to higher latitude temperature and pressure gradients and has caused surface and upper-air mid-latitude westerly wind to increase. By contrast, global temperature decreases (enhanced evaporation and cooling) occur (with a 10-15 year lag) when the THC responds to increased Atlantic salinity by undergoing a long period of above-average deep-water formation and tropical cool water upwelling. Figure 6 summarizes the physical linkages associated with the relationship between THC changes and changes in global mean temperature.

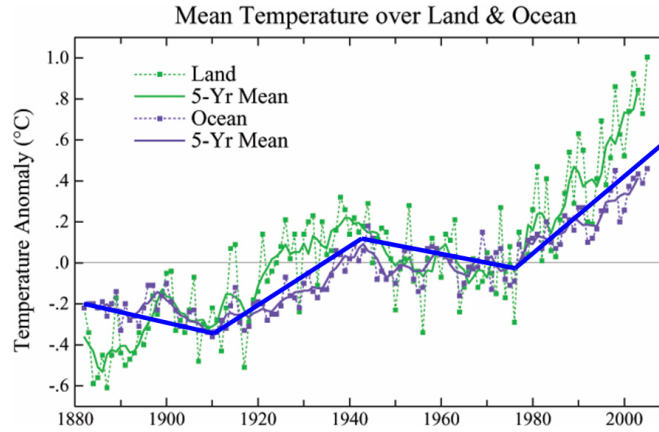


Figure 5. Change in global land and ocean temperature anomaly over the last 125 years.

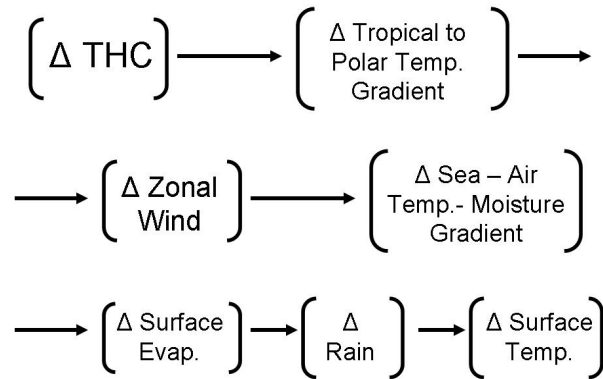


Figure 6. Progressive physical steps explaining how changes in the THC can lead to global mean temperature change. A stronger than average THC causes a decrease in rain and global warming with opposite conditions occurring when the THC is weaker than average (see Figure 8).

The rate of global ocean energy accumulation or deficit ( $\dot{E}$ ) results from an imbalance between the absorbed surface solar energy ( $S$ ) gain and the net rates of surface energy loss due to long-wave radiation ( $LW$ ), sensible heat flux ( $H$ ), evaporation ( $Evap$ ), and the thermohaline circulation ( $THC$ ). Increases in surface energy gain from  $CO_2$  gas buildups are part of the surface energy budget, but they have been typically of too small a magnitude to play a dominant role in the global temperature change that we have observed or likely will observe in the next 50-100 years. The steady-state global surface energy balance in ( $w/m^2$ ) may be expressed as in Equation 1 and Figure 7.

$$\begin{aligned}
 \dot{E} &= S + \Delta CO_2 - (LW + H + Evap + THC) \\
 \dot{E} &= 168 + (1/2 \text{ to } 1) - (66 + 24 + 78 + 3)
 \end{aligned} \tag{1}$$

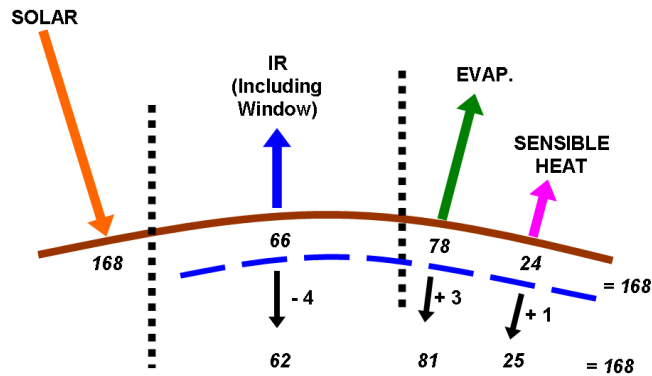


Figure 7. Global mean surface energy budget ( $\text{w/m}^2$ ) and change with  $2 \times \text{CO}_2$ .

### 3. ANALYSIS OF THE LAST 30-YEAR GLOBAL WARMING

I will assume that the solar radiation ( $168 \text{ w/m}^2$ ) absorbed by the earth's surface has not changed. The NOAA/NCEP reanalysis data (Kalnay et al., 1996) indicates that over the last 30 years there has been an increase in zonal wind (u) strength as global temperatures have risen (Figure 8). There has also been a small increase in ocean relative humidity, a general global decrease in sea minus air temperature ( $T_s - T_a$ ) gradient, a decrease in atmosphere middle level vapor and an enhancement of long wave (LW) radiation to space. These changes have caused a decrease in global surface evaporative cooling. It is this decrease in evaporative cooling which appears to have been the primary feature which has led to global mean temperature rise over the last 30 years and likely over the last century-and-a-half.

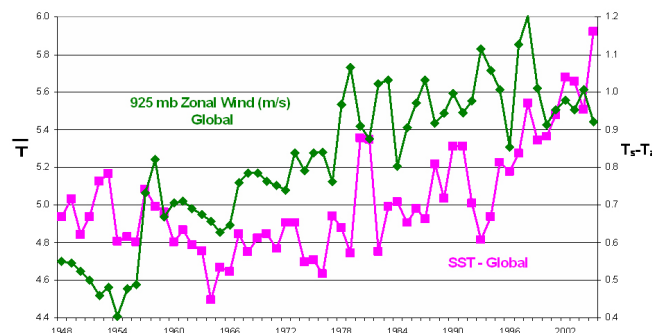


Figure 8. Reanalysis data showing the changing relationship between global average mean SST and global average low level zonal wind (925 mb) between 1950-2005.

The current scientific consensus (driven by GCM model results) views global warming of the last century and the last 30 years to be primarily a consequence of rising amounts of human-induced

greenhouse gases (primarily CO<sub>2</sub>). Rising CO<sub>2</sub> amounts have been hypothesized from the GCM model results to cause the following gradual changes:

- Global surface evaporation and rainfall increases
- Middle level moisture increase and reduced LW radiation to space
- Large upper tropospheric temperature rises in comparison with lower-level temperature rise between 40°N-40°S
- Concentrated North Polar surface temperature increases in comparison with tropical surface changes.

Carbon Dioxide (CO<sub>2</sub>) has now increased about 30 percent (378 ppm) above the pre-industrial state of 290 ppm (Figure 9). Most of this CO<sub>2</sub> increase has occurred since 1950. We might investigate how well the real global parameter changes that have taken place so far are matching the GCMs predictions of what will change from a doubling of CO<sub>2</sub>. I will refer to the early predictions of the NASA/GISS/GCM model, used by James Hanson in his testimony before Congress (1988) to predict great amounts of global warming over the next 50 years. The global warming results of this NASA model and other large government GCM models have not appreciably changed over the last 20 years. Nearly all GCM models are still indicating global average surface temperature increases of about 2-5°C with a doubling of anthropogenic greenhouse gases. Most of the GCM models have similar internal physics. They are all deficient in their assumptions on the positive water-vapor feedback loop, and all models have yet to realistically model the ocean's deep water circulation of the global thermohaline circulation (THC).

Global NCEP reanalysis data since 1950 indicate opposite changes in the global ocean-atmosphere system from most of GCM model scenarios. Since 1950, the reanalysis data indicates a general global decrease (not increase) in rainfall and middle level moisture (q). Long wave (LW) radiation to space has increased; upper tropospheric temperatures of the tropics and sub-tropics have not risen more than surface temperatures; mean polar temperatures have not shown any appreciable increase over that of surface temperature rises in the tropics. Northern hemisphere zonal winds have not weakened over the last 50 years as one would have expected by increased polar region warming compared to the tropics. By contrast, Northern and Southern hemisphere zonal winds have increased. The ocean to atmosphere

enhanced evaporation and rainfall rates have not so far followed the warming scenarios envisioned by GCMs. Global rainfall has shown a small decrease, not an increase as has been projected. It is obvious that other factors (of natural origin) have played a more dominant influence on the observed global temperature rises of the last 30 years. Global warming cannot and should not be directly tied to increases of anthropogenic greenhouse gases as GCM models have implied. The GCM models have not received the close scrutiny of the observational meteorological community that they should have. The complexity and general unavailability of their models has discouraged a careful study of their internal physics.

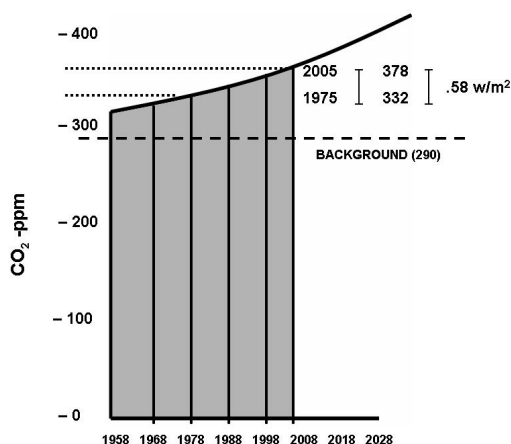


Figure 9. Change of CO<sub>2</sub> from 1958 to the present and energy change associated with this increase from 1975 to 2005.

#### 4. INFLUENCE OF CARBON-DIOXIDE (CO<sub>2</sub>) CHANGES

Pre-industrial amounts of CO<sub>2</sub> have been estimated at 290 ppm. The energy gain from a doubling of CO<sub>2</sub> to 580 ppm with all other processes held fixed has been calculated to be 4.2 w/m<sup>2</sup>. Mauna Loa Observatory measurements of CO<sub>2</sub> in ppm were 305 in 1950, 332 in 1975, and 378 in 2005. The change in CO<sub>2</sub> energy forcing from 1950 to 1975 is thus increase by  $^{27}/_{290} \times 4.2 = 0.39 \text{ w/m}^2$ ; and from 1975 to 2005 it was raised by  $^{46}/_{290} \times 4.2 = 0.67 \text{ w/m}^2$ .

These  $\Delta\text{CO}_2$  radiation energy forcing gains to the atmosphere-earth system are generally smaller than the amounts of extra energy loss/gain in the last 30 years and the last 55 years from surface variations in energy loss from long wave radiation (*LW*), sensible heat (*H*), evaporation (*Evap*) and the *THC*. Solar energy gain has been assumed constant. Table 1 gives estimated values of these other surface energy

fluxes. Note that most of the estimated eddy values of the surface source/sink values of  $\Delta LW$ ,  $\Delta H$ ,  $\Delta Evap$  and  $\Delta THC$  are larger than the calculated value of  $\Delta CO_2$ .

<i>Period</i>	$\Delta T$ ( $^{\circ}C$ )	$\Delta S$	$\Delta CO_2$	$\Delta LW$	$\Delta H$	$\Delta Evap$	$\Delta THC$
1950-1975	-0.1	0	+0.4	-1.5	+0.6	+1.0	-1.0
1975-2005	+0.5	0	+0.7	-1.8	-1.8	+2.1	+1.0

Table 1. Estimated summary of global eddy energy sources and sinks (in  $w/m^2$ ) over the two recent time periods of 1950-1975 and 1975-2005.

Reanalysis data shows that global temperature values decreased between 1950 and 1975 by  $\sim 0.1^{\circ}C$  and increased from 1975-2005 by  $\sim 0.5^{\circ}C$ . It is naïve to think that these five other surface energy sources (including solar) and sinks always sum to zero and that the only unbalancing energy source is  $\Delta CO_2$ .

## 5. TROPICAL CYCLONES

Global hurricane frequency and/or intensity has not been observed to undergo any significant trends as a result of the global warming of the last 30 years for frequency and for the last 20 years for intensity when global satellite data has been sufficient to give reliable estimates of maximum winds and MSLP. We have no theory as to why changes of global surface temperature of less than  $\pm 0.5^{\circ}C$  should cause any significant alterations in global tropical cyclone frequency and/or intensity.

One of the most misunderstood topics in tropical meteorology is the association of Sea Surface Temperatures (SSTs) and tropical cyclone frequency and intensity. Although local areas of warmer SST, such as along the Atlantic Gulf Stream and over the Gulf of Mexico loop current may act to enhance hurricane formation and/or intensity, one should not conclude that these observations support a direct SST-hurricane relationship that would also be applicable to global warming scenarios.

Such local patches of warm SST can increase local convective buoyancy (where upper-tropospheric temperature-moisture contents remain the same) and allow for the potential for greater deep cumulus convection and hurricane intensity increases. Such changes in convective buoyancy should not be expected to occur in a slow multi-decadal global warming scenario, however. Here the whole



troposphere warms in unison, global rainfall rates are not significantly altered, and the storm basin convective buoyancy patterns do not change. There is thus no reason to expect the convective buoyancy (a required component for increased hurricane activity) to become significantly greater in a global environment where mean SSTs are a little warmer than the current global temperatures.

The recent analysis of Klotzbach (2006) shows no increase in global TC frequency and intensity over the last 20 years when global mean temperatures have been rising (Figure 10 and 11), and satellite technology has advanced to the stage where reliable non-Atlantic intensity estimates can be made. Klotzbach also shows that except for the Atlantic and the Northeast Pacific, there is no significant correlation between SST and hurricane intensity in the four TC basins of the Northwestern Pacific, the North Indian, the South Indian and the South Pacific.

In distinguishing between active and inactive Atlantic basin hurricane seasons, the author and his colleagues have found that seasonal changes in SST explain just a small portion (about 10%) of the variance of seasonal and monthly hurricane activity. Other factors such as tropospheric vertical wind-shear, low-level horizontal wind-shear, middle level moisture, strength of the Atlantic equatorial trough, etc. play much more important roles in explaining Atlantic seasonal and monthly hurricane variability. This has also been found and discussed by Shapiro and Goldenberg (1998). Hurricane intensity is also a function of eye-wall size, depth of ocean mixed layer, cyclone motion, and other factors not necessarily related to SST.

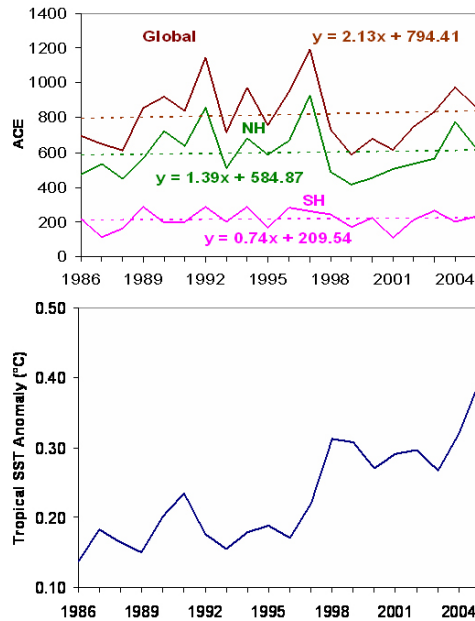


Figure 10. Accumulated Cyclone Energy (ACE) index values for 1986-2005 for the Northern Hemisphere (NH) green line, the Southern Hemisphere (SH) pink line, and the globe (brown line). Linear trends have been fitted to the three curves. Five-year running mean tropical NCEP Reanalysis SST anomalies (23.5°N-23.5°S, all longitudes) blue lines are also plotted. The base period for tropical SSTs is 1951-1980 (from Klotzbach, 2006). ACE is the sum of the square of each cyclone's maximum wind at each 6-hour measuring period.

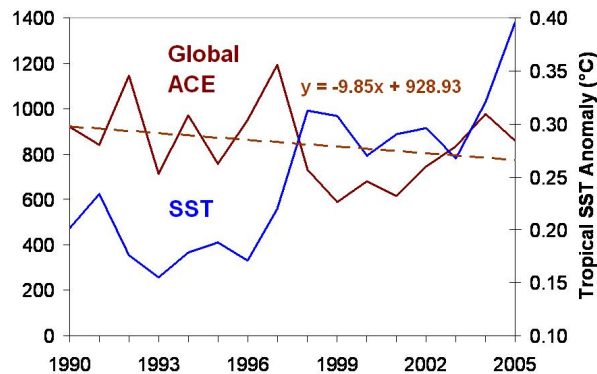


Figure 11. Global Accumulated Cyclone Energy (ACE) index values for 1990-2005 (brown line). A linear trend has been fitted to global ACE. Five-year running mean tropical NCEP Reanalysis SST anomalies (23.5°N-23.5°S, all longitudes) blue lines are also plotted. The base period for tropical SSTs is 1951-1980 (from Klotzbach, 2006).

Although the climatology of the Atlantic's major (Cat 3-4-5) hurricane activity sharply peaks around 10 September (Landsea, 1993), the Atlantic SST variations do not peak around this period. They are no higher around 10 September than they are a month earlier or a month later when major hurricane

frequency is typically much less frequent. Such strong Atlantic peaking of major hurricane activity without a similar peaking in SST shows that SST by itself is not a dominant factor.

It should also be noted that there can be quite strong high latitude tropical cyclones existing over ocean surface water temperature 3-5°C cooler than SST conditions in the tropics. In these cases the low level temperature are 3-5°C colder but the potential buoyancy can be maintained due to the middle-latitude similar or greater cooling brought about by upper-level cold air advection. Thus, it should not be expected that if the earth were to continue to warm as it has for the last 30 years that global tropical cyclone activity would necessarily be more frequent and/or more intense.

## **6. ESTIMATION OF GLOBAL WARMING RESULTING FROM A DOUBLING OF CO<sub>2</sub> FROM 290 TO 580 PPM WITH ALL OTHER PROCESSES HELD CONSTANT**

Solar and IR radiation add energy to the earth's surface at an estimated rate of ~102 w/m<sup>2</sup>. This surface energy gain is dissipated by surface evaporation cooling of 78 w/m<sup>2</sup> (76.5% of 102 w/m<sup>2</sup>) and sensible heat loss of 24 w/m<sup>2</sup> (23.5% of 102 w/m<sup>2</sup>). Assuming this to be the typical ratio of pre-and-post industrial values, a doubling of CO<sub>2</sub> to 580 ppm would add 4.2 w/m<sup>2</sup> to the earth-atmosphere system and bring about a new surface energy gain of 102+4.2=106.2 w/m<sup>2</sup>. Steady state requirements indicate that the additional 4.2 w/m<sup>2</sup> energy gain be balanced by surface evaporation increase (from 78 to 81.2 w/m<sup>2</sup>) and sensible heat increase (from 24 to 25 w/m<sup>2</sup>) – see Figure 7.

These changes would lead to a global net rainfall increase of about  $81.2/78 = 4$  percent and a surface temperature rise of about 0.2°C over the ocean and about 0.4°C over land values. This estimated global temperature increase is much smaller than the 2-5°C global temperature increase by the GCM models. The difference has to do with the GCM model assumptions of a positive water vapor feedback. As rain increases, GCMs assume that upper level water vapor increases and that this blocks LW loss to space and adds significantly larger amounts of global warming. The observations that this author has worked with for many decades do not support this assumption. Although upper level water vapor increases in areas of enhanced rainfall, there is extra subsidence drying in the clear subsidence regions both near and far from the convective areas. Overall, an increase of global rainfall does not necessarily lead to extra energy accumulation from an increased blocking of LW and extra global warming as the GCMs have assumed. This and their inability (so far) to realistically model the global ocean's deep water THC

circulation is their “Achilles-Heel.” These faulty basic assumptions have rendered GCM model predictions of future temperature change to be of little value. We should not believe any of them. They should not have influence on our government’s energy policies.

## 7. SUMMARY

It is unlikely that the sum of the five naturally occurring surface eddy energy source-sink terms of  $S'$ ,  $LW'$ ,  $H'$ ,  $Evap'$ , and  $THC'$  would always sum to zero and that the only influence on global temperature change would be the changes associated with  $\Delta CO_2$ . It is much more probable that the observed warming of the globe of the last 30 years is not a result of the changing energy source of  $\Delta CO_2$  but rather a result of an imbalance of the higher magnitude natural changing energy source-sink terms of  $LW'$ ,  $H'$ ,  $Evap'$ , and  $THC'$ . These non- $CO_2$  eddy changes are a result of the variation of the THC, and the resulting changes of the globe’s zonal circulation and rates of evaporation cooling (Figure 12).

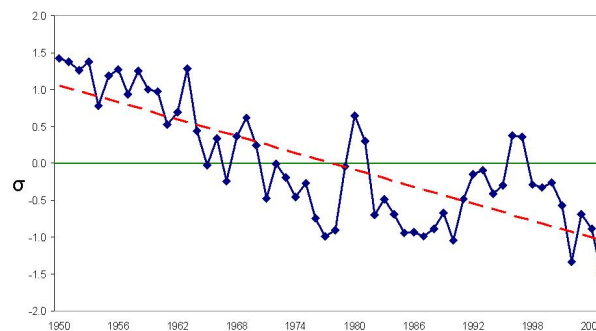


Figure 12. Reanalysis data showing the gradual decrease of the differences between global average mean SST minus global average mean surface air temperature.

It should also be noted that the globe underwent a weak cooling between 1950 and 1975 during which  $CO_2$  amounts were rising and causing a continuous mean energy gain over this 25 year period of about  $0.4 \text{ w/m}^2$ . If all of this energy went into an accumulation of temperature in the upper 100 m of the global oceans, we would see an upper mean 100 m global ocean temperature increase of  $1.1^\circ\text{C}$ . Rather the actual temperature change during this period of increased human-induced  $CO_2$  was observed to be a cooling of  $0.1^\circ\text{C}$ . There had to be other non- $\Delta CO_2$  energy processes operating during this 25 year period that were counterbalancing the changes in  $CO_2$ -induced energy gain.

The global temperature increase that has been observed over the last century-and-a-half and particularly over the last 30 years is thought to be a consequence of natural changes associated with the slow-down of the ocean's deep water THC circulation and the resulting changes in ocean and atmospheric conditions that respond to this change in  $\Delta\text{THC}$ . These  $\Delta\text{THC}$  changes caused stronger global zonal winds and less evaporation cooling. Anthropogenic changes and their potential feedback influences over the last 30 years and the last century-and-a-half could not have been of significant magnitude or timing as to have played a significant role in causing the global changes which have occurred.

## **8. PROJECTIONS OF THE NEXT FEW DECADES' GLOBAL TEMPERATURE CHANGE**

We are already 11 years into an enhancement of the THC (since 1995). Given the typical 10-15 year lag in the commencement of global cooling following the onset of a stronger than average THC, we are now likely to be at the height of the global warming we are going to see for the next several decades. I judge our present global ocean circulation conditions to be similar to that of the period of the early 1940s when the globe had shown great warming since 1910, and there was concern as to whether this 1910-1940 global warming would continue. But beginning about 15 years following the onset of a strong THC circulation in 1926, in the early 1940s, the warming began to abate. A weak global cooling began from the mid-1940s to the mid-1970s. The author projects this to be what we should expect to see in the next few decades.

Various global signals are starting to manifest themselves to indicate the start of a modest global cooling period in the coming years. These include:

1. An initial weakening of the Southern hemisphere middle-latitude zonal winds.
2. The commencement of more North Atlantic blocking patterns and Aleutian region ridge blocking. These are indicative of strong THC conditions.
3. The SST and SLPA patterns of the North Atlantic indicate a continuing strong THC and cold water upwelling in the tropics.
4. Last 9-year decrease in El Niño activity.
5. A recent beginning increase in enhanced global rainfall.

I anticipate global temperature conditions will change as they have in the past. I expect to live to see the start of a global cooling pattern and the discrediting of most of the anthropogenic warming arguments. The world has more serious problems to worry about.

## 9. REFERENCES

Kalnay, E., and Coauthors, 1996: The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, **77**, 437-441.

Klotzbach, P.J., 2006: Trends in global tropical cyclone activity over the past twenty years (1986-2005). Submitted to *Geophys. Res. Lett.*

Landsea, C., 1993: A climatology of intense (or major) Atlantic hurricanes. *Mon. Wea. Rev.*, **121**, 1703-1714.

Shapiro, L.J., and S.B. Goldenberg, 1998: Atlantic sea surface temperatures and tropical cyclone formation. *J. Climate*, **11**, 578-590.

***“It is fiction. But it has the absolute ring of truth.”***

Larry Nation, spokesman for the American Association of Petroleum Geologists, which awarded its annual journalist award to Michael Crichton, whose latest novel, **State of Fear**, dismisses global warming as a conspiracy.

*Time Magazine* (February 20, 2006)